

# **PHOSPHORUS CONTROL ACTION PLAN**

**and TMDL Report**

## **THREECORNERED POND**

**Kennebec County**



### **Threecornered Pond PCAP-TMDL Report**

**DEPLW 2002 - 0562**



**Maine Department of Environmental Protection**

**and the Maine Association of Conservation Districts**

**Public Review DRAFT**

**March 8 to April 7, 2003**

# **THREECORNERED POND Phosphorus Control Action Plan**

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## ACKNOWLEDGMENTS

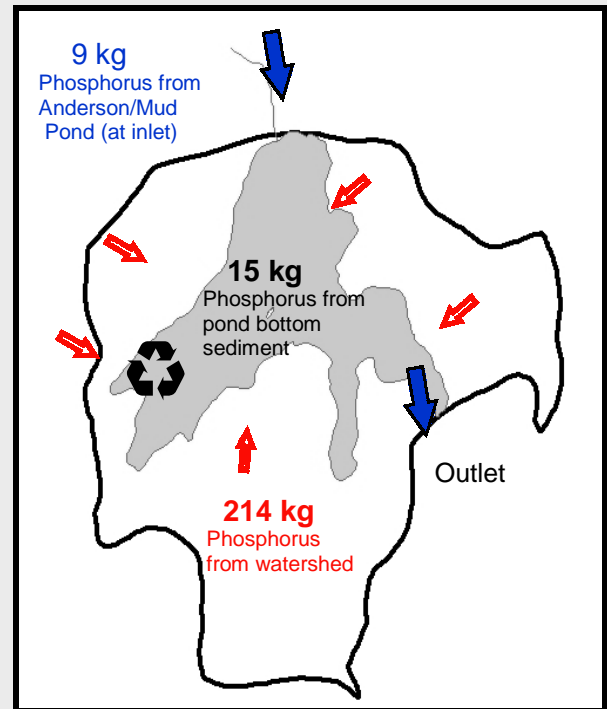
*In addition to Maine DEP and US-EPA Region I staff, the following individuals and groups were instrumental in the preparation of this Threecornered Pond Phosphorus Control Action Plan Report: MACD watershed inventory staff (Jodi Michaud Federle, Tim Bennett and Forrest Bell); Kennebec County SWCD (Nate Sylvester and Dale Finseth); China Region Lakes Alliance (Reb Manthey and Jon Van Bourg); the City of Augusta (Leif Dahlin, Leo St. Peter, Bruce Keller) and Town of Vassalboro officials and office staff; the Threecornered Pond Improvement Association (with special thanks to Phil and Jany Choate for providing lake access for sampling, and Joan Jones for her assistance); past and present VLMP monitors (Jane Weeks, Joyce Small, Joan Jones and Leo St. Peter); the Maine Forest Service (Morten Moesswilde); the Maine Department of Agriculture (David Rocque); and the Maine Department of Inland Fish & Wildlife (Jim Lucas).*

# THREECORNERED Pond Phosphorus Control Action Plan Summary Fact Sheet

## Background

**THREECORNERED POND** is a 180-acre waterbody located in Augusta in Kennebec County, south central Maine. Threecornered Pond has a direct watershed area of about 3,272 acres (5.1 square miles) located within Augusta, Vassalboro and to a lesser extent, Windsor. This pond has a maximum depth of 41 feet, a mean depth of 16 feet; and a **flushing rate** of 3.24 times per year. Threecornered Pond, along with Threemile Pond is part of the total Webber Pond watershed drainage area which includes both Threemile and Threecornered pond subwatersheds (22.5 square miles).

The water quality of Threecornered Pond is considerably better than Threemile and Webber, however there is still a declining trend in water clarity. Phosphorus is naturally occurring in area soils and soil erosion in lake watersheds can have far-reaching lake consequences. Soil particles transport the phosphorus, which essentially “fertilizes” the lake and decreases water clarity. Excess phosphorus can also harm fish habitat and lead to nuisance algae blooms. Studies have also shown that as water clarity decreases lakeshore property values also drop.



## Stakeholder Involvement

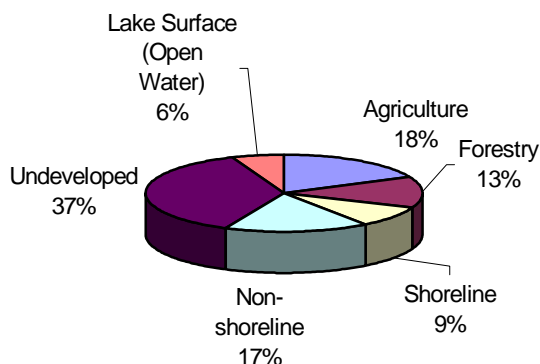
With these issues in mind, federal, state, county, and local groups have been working together to address the problem. In 2001, the Maine Department of Environmental Protection funded a project in cooperation with the Maine Association of Conservation Districts, Kennebec County Soil and Water Conservation District, China Region Lakes Alliance, and the Threecornered Pond Improvement Association to identify and quantify the potential sources of phosphorus and identify the need for **Best Management Practices** to be installed in the watershed. A final draft report, completed in march of 2003, is entitled “Threecornered Pond Phosphorus Control Action Plan” and doubles as an official **TMDL** report that will be submitted to the U.S. Environmental Protection Agency, New England Region, for formal review and approval.

## What We Learned

A land use assessment was conducted for the Threecornered Pond watershed to determine potential sources of phosphorus that may run off from land areas during storm events and springtime snow melting. This assessment involved utilizing many resources, including generating and interpreting maps, inspecting aerial photos, and conducting field surveys. Similar assessments have been conducted for associated downstream Threemile and Webber ponds, located in the neighboring towns of China, Vassalboro and Windsor.

Land use assessment results estimate that 214 kilograms (kg) of phosphorus per year is exported to Threecornered Pond directly from the external watershed. The pie chart depicts the phosphorus load by land use for the Threecornered Pond watershed.

**Threecornered Pond Phosphorus Load = 214 kg/yr**

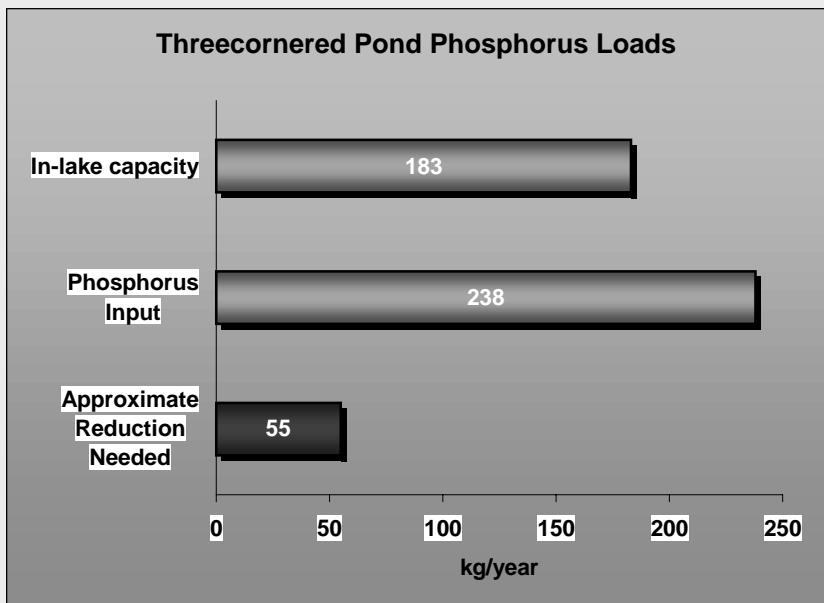


The amount of phosphorus being recycled internally from the bottom sediments of Threecornered Pond during the summertime is 15 kg. The graph at right displays the estimate that the internal (15 kg) + external (214 kg + 9 kg) = (238 kg) loading exceeds Threecornered Pond's capacity (183 kg) to effectively process phosphorus. The amount needed to be reduced on an annual basis to ensure that Threecornered Pond is free of nuisance summertime algae blooms approximates 55 kg.

### What Can You Do To Help?

As a watershed resident or land user there are many things you can do to protect Threecornered Pond. Lakeshore owners can use phosphorus free fertilizers and maintain natural vegetation adjacent to the lake. Agricultural and commercial land users can consult the Kennebec County Soil and Water Conservation District or Maine DEP for information regarding Best Management Practices for reducing phosphorus. Watershed residents can become involved by volunteering to help the Threecornered Pond Improvement Association and participating in events sponsored by the China Region Lakes Alliance.

All stakeholders and watershed residents should attempt to learn more about their lake and the many resources available, including the full version of the Threecornered Pond Phosphorus Control Action Plan. This report, which provides a detailed account of the project and recommendations for future BMP work, can be viewed on line at the Maine DEP website ([www.state.me.us/dep/blwq/comment.htm](http://www.state.me.us/dep/blwq/comment.htm)) or a hard copy can be obtained at Maine DEP in Augusta.



*This shoreline dwelling has a naturally vegetated buffer that will help to reduce runoff into Threecornered Pond.*

### **Key Terms**

- A **watershed** is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.
- The **flushing rate** refers to how often the water in the entire lake water is replaced.
- **Phosphorus**: is one of the major nutrients needed for plant growth. It is naturally present in small amounts and limits the plant growth in lakes. Generally, as phosphorus increases, the amount of algae also increases.
- **Best Management Practices** are techniques to reduce sources of polluted runoff and their impacts. BMP's are low cost, common sense approaches to reduce storm runoff and velocity to keep soil out of lakes and tributaries.
- **TMDL** is an acronym for Total Maximum Daily Load which represents the total amount of a pollutant that a waterbody can withstand and still meet water quality standards.

## Project Premise

This project, funded through a 319-grant from the United States Environmental Protection Agency (EPA) and the Maine Department of Environmental Protection (DEP), was directed and administered by the Maine Association of Conservation Districts (MACD) in partnership with Maine DEP (Augusta) from the summer of 2001 through the early spring of 2003.

The objectives of this project were twofold: First, a comprehensive land use inventory was undertaken to assist Maine DEP in developing a Phosphorus Control Action Plan (PCAP) and a Total Maximum Daily Load (TMDL) report for the Threecornered Pond watershed. Simply stated, a TMDL is the total amount of **phosphorus** that a lake can accept without harming water quality (See Appendices). The Maine DEP, with the assistance of the MACD Project Team and the Kennebec County Soil and Water Conservation District, will incorporate public comments before final submission to the US EPA. *(For more specific information on the TMDL process and results, refer to the appendices or contact Dave Halliwell at the Maine DEP Augusta Office at 287-7649 or at David.Halliwell@maine.gov).*

Secondly, watershed survey work, including a shoreline, septic and town roads survey evaluation, was conducted by the MACD project team to help assess direct drainage nonpoint source (NPS) pollution sites and **total phosphorus** reduction techniques that would be beneficial for the Threecornered Pond watershed. The MACD Project Team did not attempt to conduct a full-scale watershed survey for Threecornered Pond since the China Region Lakes Alliance (CRLA) intends to conduct a cursory watershed survey in the spring of 2003. Instead, a limited survey focused on the state and town roadways and numerous camp/private roads as well as the shoreline of Threecornered Pond. The results of this limited survey are intended to be a source of additional information on NPS pollution sites for the CRLA, the Threecornered Pond Improvement Association (TPIA), and the watershed municipalities of Augusta, Vassalboro and Windsor. It is anticipated that the mitigation of these sites can be addressed using available programs and resources through the CRLA, the TPIA, the Kennebec County Soil and Water Conservation District and Maine DEP.

**Note:** In order to protect the confidentiality of landowners in the watershed, site-specific information has not been provided as part of this report.

**Total Phosphorus (TP)** - is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in lakes. Generally, as the amount of lake phosphorus increases, the amount of algae also increases.

**Nonpoint Source (NPS) Pollution** - is polluted runoff that originates from numerous, small sources as opposed to a direct (or point) source.

The Phosphorus Control Action Plan project compiled and refined land use data that was derived from various sources, including watershed municipalities, Threecornered Pond Improvement Association, Kennebec County Soil and Water Conservation District, and the CRLA. Local citizens, watershed organizations, and conservation agencies should benefit from this compilation of data as well as the watershed assessment and Best Management Practice (BMP) recommendations. Above all, this document is directly intended to help Threecornered Pond stakeholder groups effectively prioritize future BMP work in order to obtain the resources necessary for implementation of NPS pollution mitigation work in the watershed.

## Research Methodology

Threecornered Pond background information was obtained using several methods, including a review of a previous 314 Diagnostic Feasibility study of the watershed area completed by Maine DEP in 1982, as was water quality monitoring data provided by the Maine DEP supported the Volunteer Lake Monitor Program (VLMP), numerous phone conversations and personal interviews with municipal officials, regional organizations and agencies, and several field tours of the watershed, including boat reconnaissance of the lake and shoreline.

Land use data were determined using several methods, including (1) **Geographic Information System (GIS)** map analysis, (2) analysis of topographic maps, (3) analysis of town property tax maps and tax data, (4) analysis of aerial photographs (1992 & 1997) and (5) field visits. Much of the undeveloped land use area (i.e., forest, wetland, grassland) was determined using GIS maps utilizing data from the Penobscot Bay Land Cover 1995/96 for the Coastal Change Analysis Program. The developed land use areas were obtained using the best possible information available through analysis of methods 2 through 5 listed above. Necessary adjustments to the GIS data were made using best professional judgment.

*GIS—or geographic information system combines layers of information about a place to give you a better understanding of that place. The information is often represented as computer generated maps.*

Roadway data were gathered by taking actual road width measurements of the various types of roads (state, town, private/camp) in the watershed. The roads were measured between the two outer edges of the roadside ditches or berms. An average width was used for each of the three road types. Final measurements for all roadways within the watershed were extrapolated using GIS and USGS topographical maps. The roadway area was determined using linear distances and the average of 3 to 5 width measurements for each of the three main road types. Additional land use data (i.e. residential, institutional) were determined using GIS, aerial photos, topographic and property tax maps as well as personal consultation and field visits.

Agricultural information within the Threecornered Pond Watershed was provided by the Kennebec County Soil and Water Conservation District (SWCD). Information regarding forestry harvesting operations was provided by the Maine Forest Service, Department of Conservation.

### **Study Limitations**

Land use data gathered for the Threecornered Pond Watershed is as accurate as possible given available information and resources utilized. However, the final numbers for the land use analysis and phosphorus loading graphics are approximate at best, and should be viewed as reasonable estimations only.

# THREECORNERED Pond Phosphorus Control Action Plan

## DESCRIPTION of WATERBODY and WATERSHED

**Threecornered Pond** is a single-basin 180-acre (0.3 square miles ) drainage lake located in Augusta (DeLorme Atlas, Map 13), within Kennebec County in south central Maine. Threecornered Pond has a **direct** watershed area of 3,272 acres (5.1 square miles) within Augusta, Vassalboro and Windsor. Threecornered Pond has a maximum depth of 33 feet, an overall mean depth of 11 feet and a flushing rate of 3.24 times annually. The **total** Threecornered Pond watershed drainage area includes the subwatershed of Anderson Pond (a.k.a. Little Mud or Evers Pond), which is considered in this report as an **indirect** external watershed load.

*The **direct watershed** refers to the land area that drains to the lake without first passing through another lake or pond.*

**Drainage System:** Threecornered Pond is the headwater source for a chain of lakes that make up the entire Webber Pond watershed. Threecornered Pond, to the southwest, flows southeast to join with the Mud Pond outlet stream, and continues to flow northeast to drain into Threemile Pond at its southern end. Threemile Pond outlets to Webber Pond via Seaward Mills Stream, located at the northwest end of the pond. Webber Pond then flows southwest into the Kennebec River via its outlet (Sevenmile) stream. A number of intermittent and perennial streams drain into Threecornered Pond with Stony Brook being the major tributary, located at the north end of the pond (Maine DEP 1982). Threecornered Pond has a single outlet at the dam closest to the Weeks Mills Road.

## WATER QUALITY INFORMATION

Threecornered Pond is listed on the Maine Department of Environmental Protection's 303(d) list of lakes that do not meet State water quality standards as well as the State's **Nonpoint Source Priority Watersheds** list. Hence, a draft action plan (and TMDL) was completed in the winter of 2003.

Water quality data for Threecornered Pond has been collected noncontinuously since 1976 through the Maine DEP VLMP inconsistently since 1976. Based on **Secchi disk transparencies** and measures of total phosphorus and **chlorophyll-a**, the water quality of Threecornered Pond is considered to be declining and the potential for nuisance summertime algae blooms is moderate (VLMP 2002).

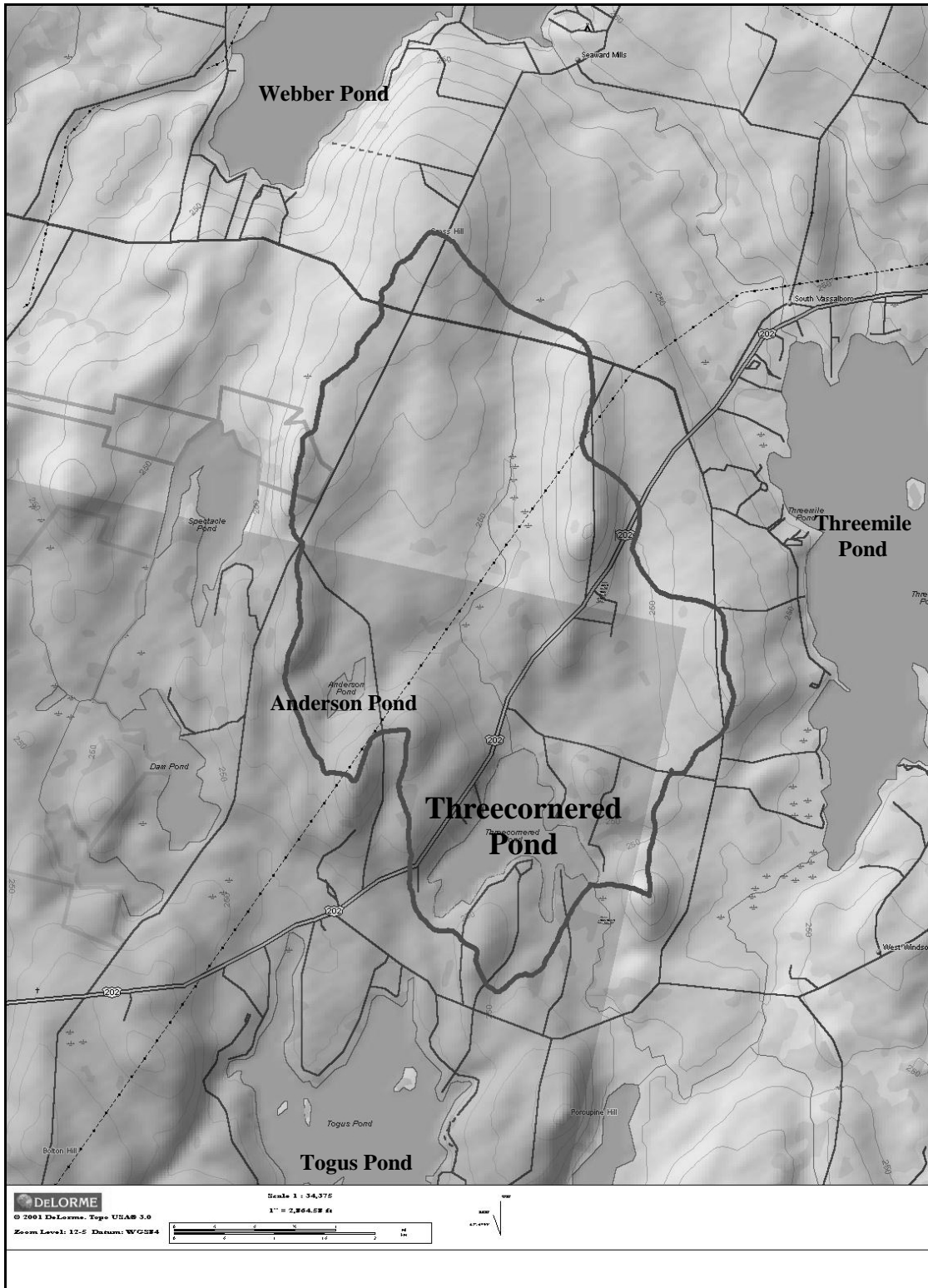
Nonpoint source (overland) pollution is the main reason for declining water quality in Threecornered Pond. During and after storm events, nutrients such as phosphorus—naturally found in Maine soils—drain into the lake from the surrounding watershed by way of streams and overland flow.

*181 lakes were listed on the **Nonpoint Source Priority Watersheds** list released by the Maine Department of Environmental Protection in 1998. Webber Pond was listed among 41 lake watersheds as the “highest priority”. This list and the evaluation process used to determine the list are available on the Maine DEP website: [www.state.me.us/dep/blwq/docwatershed/prilist5](http://www.state.me.us/dep/blwq/docwatershed/prilist5)*

***Secchi Disk Transparency**—a measure of the transparency of water (the ability of light to penetrate water) obtained by lowering a black and white disk into water until it is no longer visible.*

***Chlorophyll-a** is a measurement of the green pigment found in all plants including microscopic plants such as algae. It is used as an estimate of algal biomass—the higher the Chl-a number, the higher the amount of algae in the lake.*

**Figure 1: Threecornered Pond Watershed**



Phosphorus can be thought of as a fertilizer—a primary food for all plants, including algae. Phosphorus is naturally limited in lakes. When lakes receive excess phosphorus from NPS, it “fertilizes” the lake by feeding the algae. Too much phosphorus can result in algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the entire community.

**Public Access:** The City of Augusta owns and operates the Bicentennial Nature Park, which began operating in July of 2001 and is limited to Augusta residents only. The park encompasses approximately 25 acres on the southeastern shore of Threecornered Pond off of Route 3. There is not a sandy beach area, but a docking system that provides lake access to a cordoned swim area, complete with a floating dock (see photo at right). There are picnic tables and grills on-site. Access for canoes and kayaks (hand-carry only) is provided as well as a designated fishing area and limited nature trails that connect the park to the parking area, which consists of two larger gravel parking areas and several smaller parking ‘pods’ designated for cars with canoes or kayaks. The maximum capacity is 54 cars or 150 people.



An unofficial public access site is located off the Lamson Road at the stream crossing where people park on the side of the road and hand carry canoes and kayaks to the water. There are no public campgrounds.

**Human Development:** Dominant human use of Threecornered Pond shoreline is residential (both seasonal and limited year-round occupancy) and recreational – including fishing, boating, and beach use. Threecornered Pond is a relatively undeveloped lake with many large shoreline lots, especially on the western and northeastern shorelines of the pond. Only about 20 to 25 percent of the shoreline area is currently developed (MACD 2002). There are 43 shoreline dwellings, of which 72% are seasonal cottages and 28% are year-round homes (Augusta Tax Records, MACD 2002). The threat of seasonal to year-round conversions is not of great concern. Within the last decade, there has been only a single conversion from seasonal to year-round (George Soucy, Augusta CEO, personal communication).

The Fox Glen subdivision is a 1930's subdivision located at the south end of the pond encompassing an area of approximately 155 acres. According to the City of Augusta tax records, this subdivision is not completely developed. The perimeter of the subdivision borders Threecornered Pond on three sides, with the interior lots having access via designated right-of-ways. This area is noted for its potential for future development.

The entire Threecornered Pond watershed is located within the towns of Augusta (49%), Vassalboro (47%) and, to a small extent, Windsor (4%) (KC-SWCD GIS). Vassalboro and Windsor

are rural, residential suburbs. The City of Augusta proper is the commercial and employment center of the area. Population growth rates have increased during the 1990-2000 time period for the towns of Vassalboro (10%) and Windsor (16.3%), while Augusta's population decreased by 13% (US Census 1990, 2000). The estimated watershed population is 530 (MACD 2002).

Threecornered Pond is within the Lower Kennebec River Watershed. The Kennebec River watershed has the state's highest concentration of threatened lakes and lakes in non-attainment of water quality standards (Maine DEP 1998). Threecornered Pond is on the State's list of lakes that are designated at "Most at Risk From Development".

**Water Level (Dam) Management:** The Threecornered Pond Improvement Association owns and maintains the dam located at the outlet at the southeastern corner of the pond. The dam features a wide opening (or runoff bay) with provisions to add and remove stop boards. Each year a representative of the association volunteers to adjust the stop boards to manage water levels. It is the goal of the Association to maintain natural flow and water level conditions to the maximum extent possible (TPIA Draft Plan 2002).

The proposed policy for 2002 was to remove two stop boards in late September/early October and replace the boards by mid-November with the intent to drain the high algae-laden waters, minimize winter ice damage as well as habitat disturbance to fur-bearing animals (TPIA Draft Plan 2002).

### **Fish Assemblage - Fisheries Status Report**

Based on records provided by the Maine Department of Inland Fisheries and Wildlife (Maine DIFW) and a recent phone conversation with fish biologist Jim Lucas (Region B, Sidney Maine DIFW office), **Threecornered Pond** (Augusta, Kennebec River – Seven Mile Stream drainage) is currently managed as a warmwater fishery only and was last surveyed in 1963 (revised 2002). There is currently no stocking of fish since there is no official public access. Unlike downstream lakes (Threemile and Webber ponds), Threecornered Pond is not currently part of the Maine Department of Marine Resources anadromous fish (alewife) restoration program.

A total of **12 fish species** are listed, including: **9 native indigenous fishes** (American eel, Golden shiner, White sucker, Brown bullhead, Chain pickerel, Banded killifish, Redbreast sunfish, Pumpkinseed, and Yellow perch); and **3 introduced fishes of uncertain origin** (White perch, Smallmouth and Largemouth bass). These latter three non-indigenous sportfish species, along with Chain pickerel, provide for a popular warmwater fisheries in Threecornered Pond. Similar to neighboring Webber Pond (June 2002), there have been recent (1998) unverified records of larger illegally introduced Northern pike being angled from Threecornered Pond.

Based on the premise that reducing algal productivity will ultimately reduce dissolved oxygen losses - then a significant reduction in the external (watershed) load of total phosphorus to **Threecornered Pond** may enhance and protect its warmwater fisheries.

**Watershed Soils:** (Source: USDA SCS 1978) Soils dominating the Threecornered Pond watershed are fine to medium textured and are easily erodible when vegetation is removed (CRLA 1999) and are classified by the three soil associations:

1. **Hollis-Paxton-Charlton-Woodbridge** (82%). Shallow and deep, somewhat excessively drained to moderately well-drained, gently sloping to moderately steep, moderately coarse textured soils, on hills and ridges.
2. **Buxton-Scio-Scantic** (12%). Deep, moderately well-drained to poorly drained, nearly level to sloping, medium textured soils, in flat areas near waterways.
3. **Scantic-Ridgebury-Buxton** (6%). Deep, poorly drained to moderately well-drained nearly level to sloping, medium textured soils in valleys and moderately coarse textured soil in flat areas or depressions on upland ridges. (Maine DEP 1981).

### **Land Use Inventory**

Results of the Threecornered Pond watershed land use inventory are depicted in Table 1. The various land uses are categorized by developed vs. undeveloped land. The developed land area comprises 14% of the watershed and the undeveloped land, including the surface area of Threecornered Pond, comprises approximately 86% of the watershed. These numbers may be used to help make future planning and conservation decisions relating to the Threecornered Pond Watershed. Information from this table was used as a basis for preparing the Total Maximum Daily Load report (see Appendices).

### **Descriptive Land Use and Phosphorus Export Estimates**

**Agriculture:** In 1981, Maine DEP conducted a Diagnostic Feasibility Study for the entire Webber Pond Watershed, inclusive of both Threemile and Threecornered Pond watersheds. High phosphorus loading was attributed to poor manure handling techniques (winter spreading on cropland) and inappropriate nutrient management (Maine DEP 1982). In 1983 a watershed management plan, including a comprehensive listing of needed agricultural conservation practices for the Webber, Threemile and Threecornered Pond watersheds, was developed by the Kennebec County SWCD and Natural Resources Conservation Service (NRCS).

Recent agricultural land use data for the Threecornered Pond direct watershed were provided by the Kennebec County SWCD and confirmed by aerial photo analysis (1992 and 1997) and ground-truthed with the assistance of Kennebec County SWCD staff. Today, there are approximately 133 acres of agricultural land within the Threecornered Pond watershed, comprising 4% of the total land area and 18% of the external phosphorus load.

**Forestry:** Forestry operations generally have the potential to negatively impact a waterbody by soil erosion and sedimentation from highly disturbed logging sites. Many local consulting foresters have worked with the CRLA to minimize potential negative impacts. Also, many local loggers are *Certified Logging Professionals* trained to reduce potential environmental impacts associated with forestry (CRLA 1999). Acreage of “operated forest” is an estimate of forest acres harvested annually in the

**Table 1: Land Use Inventory for the Threecornered Pond Watershed**

LAND USE	Total Area Acres	Total Land Area %	TP Export Ave %
<b>Agricultural and Forestry practices</b>			
Cropland	31	0.9%	8.7%
Hayland	65	2.0%	8.0%
Low-Intensity Hayland	37	1.1%	1.4%
Operated Forestland	171	5.2%	12.9%
<b>Sub-totals</b>	<b>303</b>	<b>9%</b>	<b>31%</b>
<b>Shoreline development</b>			
Low impact residential	9	0.4%	0.5%
Medium impact residential	11	1.0%	1.7%
High impact residential	3	0.4%	0.5%
Septic Systems			2.3%
Camp & Private Roads	9	3.5%	4.6%
Recreational	4	1.5%	1.9%
<b>Sub-totals</b>	<b>35</b>	<b>1%</b>	<b>9%</b>
<b>Non-shoreline development</b>			
State Roads	19	0.0%	0.2%
Town Roads	23	0.8%	5.8%
Trails	1	0.0%	
Low Density Residential	66	4.0%	4.8%
Commercial	5	0.2%	1.4%
<b>Sub-totals</b>	<b>115</b>	<b>4%</b>	<b>17%</b>
<b>Total Ag/Forestry/Development</b>	<b>453</b>	<b>14%</b>	<b>57%</b>
Inactive/Passively Managed Forest	1,904	58.2%	14.4%
Wetlands	266	8.1%	10.1%
Scrub Shrub	262	8.0%	5.0%
Reverting Fields	204	6.2%	7.7%
Bare Land	2	0.1%	0.3%
<b>Undeveloped</b>	<b>2,639</b>	<b>81%</b>	<b>37%</b>
<b>Total Open Water</b>	<b>180</b>	<b>6%</b>	<b>5%</b>
<b>TOTAL DIRECT WATERSHED</b>	<b>3,272</b>	<b>100%</b>	<b>100%</b>

Threecornered Pond watershed. Operated forestland within the Threecornered Pond watershed represents 5% of the land area and 13% of the total phosphorus load. (Forestry data and interpretation provided by Morten Moesswilde, Maine Forest Service).

Maine landowners who harvest more than 2 acres of forest (or 5 acres if partially cut) are required to submit a Forest Operations Notification, including a location map, to the Maine Forest Service, Department of Conservation. After harvest, a Landowner Report of acres actually harvested in a given year is required. These reports provide a reasonable average annual estimate of those acres where some type of partial timber harvesting took place. The estimated “operated forest” acreage for the Threecornered Pond watershed, based on Landowner Reports submitted for 1998 – 2001, is 171 acres. No clearcutting operations were reported for the 1998 –2001 time period in the Threecornered Pond watershed.

Harvested forest acres in Maine typically regenerate as forest, whether or not they are under any type of planned forest management or under the supervision of a Licensed Forester. Forest areas without harvesting may be managed passively, or may be under an active management program with no commercial activity occurring during the 1998-2001 time period. Landowner reports show that no forest acres have been cleared with the intention of converting the land to another use.

**Shoreline Camp and Residential Lots:** In order to evaluate the potential impact of lakeshore homes, project staff conducted a shoreline residential survey in the summer of 2002. This visual survey was carried out from a canoe while observing the Threecornered Pond shoreline and the results are based on subjective determinations of potential impact rates using best professional judgment. The visual survey included a residential structure tally along with estimating a potential impact rating ranging from 1 to 5, with 1 being low impact and 5 being high-impact. A lot given a score of 1 would be a best case scenario, generally undeveloped and having a full naturally occurring vegetated buffer. Conversely, a lot given a score of 5 would be a worst case scenario, exhibiting little or no vegetative buffer (natural or ornamental) and evidence of bare (eroding) soil - a visible source of phosphorus input to the lake. In addition to the impact rating, project staff evaluated the residency status of the dwelling (seasonal vs. year-round) and estimated the relative distance of the dwelling to the lake and the percent slope of the lot.

The lake shoreline housing count estimates 31 seasonal and 12 year-round dwellings on the immediate shoreline of Threecornered Pond (MACD 2002). A summary of the findings of the survey for Threecornered Pond is depicted in Table 2. In order to protect landowner confidentiality, site-specific information is not provided as part of this study.

Relevant findings of the shoreline residential survey show a low percentage (10%) of high impact lots on Threecornered Pond and a high percentage of lots (50%) with “good” natural vegetation present. There is also a relatively high percentage of steep slopes along the shoreline (28%) and a high percentage of dwellings less than 100 feet from Threecornered Pond (56%).

Phosphorus loading from Threecornered Pond shoreline residential areas is categorized into low, medium, and high impact rating classes. Phosphorus loading coefficients were developed using information on residential lot stormwater export of algal available phosphorus (Dennis et al. 1992). Shoreline lake residences comprise only 0.7% of the total land area of the watershed is developed shoreline and contribute approximately 1.8% of the total watershed (external) phosphorus load to Threecornered Pond (not inclusive of septic systems) . Low impact sites contribute only 0.4% of the TP-load, medium impact sites contribute 1%, and high impact sites contribute 0.4% of the external, watershed derived TP-load to Threecornered Pond.

**Table 2: Results of 2002 Threecornered Pond Shoreline Survey**

<u>Variable</u>	<u>Number</u>	<u>Percent</u>
Total number of lots surveyed	60	n/a
Number of developed lots	43	72%
Average impact rating	2.7	n/a
Dwellings less than 100' from lake	24	56%
Dwellings on steep slope of more than 10%	12	28%
"Good" natural vegetation present	30	50%
"High impact" lots	6	10%
"Medium impact" lots	20	33%
"Low impact" lots	17	28%

**Septic Systems:** It is important to consider the potential for total phosphorus loading from shoreline septic systems keeping in mind that more than half of the dwellings are less than 100' from the lake and the prevalence of steep slopes. Much of the shoreline is dominated by Paxton-Charlton very stony fine sandy loams, with slopes ranging from 3 – 30% (USDA SCS 1978). These soils are nearly ideal for septic systems with enough silt and clay for treatment of the effluent, but coarse enough to handle the hydraulics as well as a restrictive layer that protects the true water table (David Rocque, ME Dept. of Agriculture, personal communication). Currently, there are no public sewer services for the land areas within the Threecornered Pond shoreland zone area (City of Augusta).

- To convert kg of total phosphorus to pounds—multiply by 2.2046
- To convert kg/hectare to lbs/acre—multiply by .892

In order to estimate total phosphorus loading from shoreline septic systems, a simple model was developed based on the following attributes: occupancy status (seasonal or year-round); estimated age of the system; and estimated distance of the system to the lake. These latter attributes were determined by shoreline survey, town records and personal interviews with City of Augusta officials. An average occupancy rate of 3 people per dwelling was used (US EPA 2001b).

Estimates of the total phosphorus loading from residential septic systems on Threecornered Pond ranged from a low of 4 to a high of 13 kg (7 kg/yr average) of total phosphorus per year. Estimates of

the phosphorus loading from recreational (Bicentennial Park) septic system ranged from a low of 1 to a high of 3 kg total phosphorus per year. Combined residential and commercial shoreline septic system loading approximates an average watershed phosphorus export of 2.3% or 5 kg TP annually.

**Recreational (Shoreline):** Included in this category is Augusta's Bicentennial Nature Park comprising approximately 4 acres out of 25 total currently 'developed'. The park includes a swimming area, roads, parking lots, walking trails, modified open space, a changing/bathroom area and septic system. The City park property also encompasses a seasonal cottage and garage. This shoreline land use accounts for 1.5% of the total phosphorus load to Threecornered Pond.

**Private/Camp Roadways:** Camp roads have the potential to negatively impact water quality due to close proximity to the lake, steep slopes and poor gravel road maintenance. There are four miles of private/camp roads on a total of six private/camp roads adjacent to Threecornered Pond. This shoreline land use accounts for 0.3% of the total land area and 3.5% of the total phosphorus load.

Overall, shoreline development comprises 1% of the total watershed area and contributes an average of 19 kg of phosphorus annually, which approximates 9% of the estimated external (watershed generated) phosphorus load.

### **Other Development and Land Uses**

These areas consist of lands such as state and town roadways, low-density non-shoreline residential areas and commercial areas. These land use areas were calculated using GIS land use coverage provided by the Kennebec County Soil and Water Conservation District, as well as tax data, aerial photos and field visits.

**Non-Shoreline Development:** All lands outside the immediate shoreline area of Threecornered Pond, including residential areas, commercial and recreational (public) areas.

**Public Roadways:** Public roads are divided into two categories – state public highway and town public highway. There are only 2 miles of state roadway and 6 miles of town roads and less than 1 mile of trails. Public Roadways characteristically account for a much greater percentage of the phosphorus load (12.4%) versus its land area (1.3%) in the Threecornered Pond watershed.

**Non-Shoreline Residential Areas** in the watershed were determined using GIS land use cover provided by the KC-SWCD, the City of Augusta and the Town of Vassalboro tax assessors' records and property tax maps, and by ground-truthing by MACD project staff (traveling all roads within the watershed). Non-shoreline residential areas are characterized by dispersed, low-density, single-family homes. Residential area was determined by counting every dwelling away from the immediate shoreline (133 dwellings) and multiplying by the estimated average cleared lot area (0.5 acres)—for an estimated 66 acres of non-shoreline residential area in the watershed. Low-density residential areas represents 2% of the total land area and 3.1% of the total phosphorus load.

**Commercial:** Commercial development within the watershed is limited to a small area – ca. 5 acres, consisting of a restaurant/bar establishment and several small retail shops. Commercial land area accounts for only 0.2% of the watershed area and 1.4% of the total phosphorus load.

Overall, the developed land area comprises 14% of the total watershed area and contributes an average of 122 kg of phosphorus annually, which approximates 57% of the estimated external (watershed generated) total phosphorus load.

### **Phosphorus Loading from Undeveloped Lands**

**Forests:** Of the total land area within the Threecornered Pond watershed, 58% (1,904 acres) is naturally forested, characterized by privately-owned deciduous and mixed forest plots (KC-SWCD GIS, MACD 2002). About 14% of the phosphorus load is estimated to be derived from unmanaged forested areas within Threecornered Pond's direct drainage area.

**Other Undeveloped Land Areas:** Combined wetlands, reverting fields, scrub shrub and bare land comprise accounts for the remaining 23% of the non-cultural total phosphorus export load.

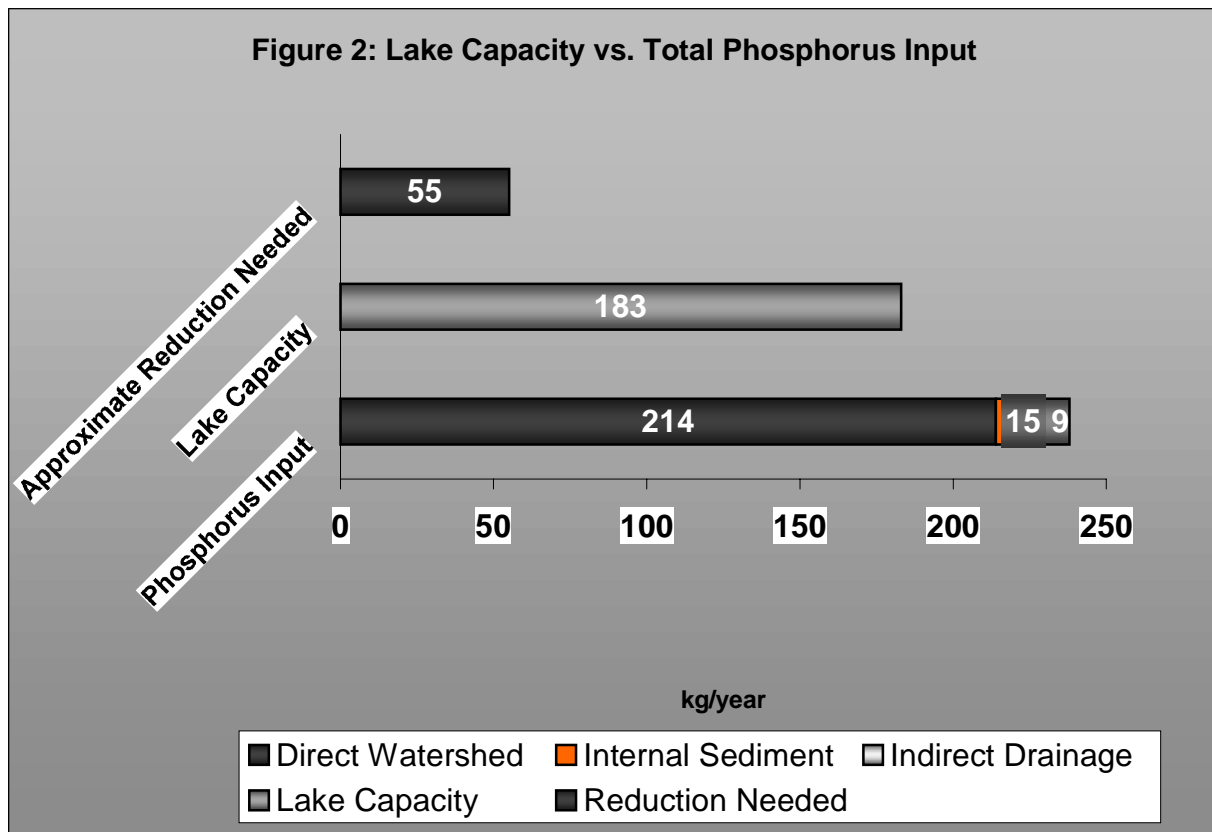
**Atmospheric Deposition (Open Water):** Threecornered Pond surface waters (180 acres) comprise 6% of the total watershed area (3,272 acres), representing 5% of the total phosphorus load entering Threecornered Pond.

Summary: Overall, the undeveloped land area comprised 81% of the total watershed area and contributes an average of 92 kg of phosphorus annually, which approximates 42% of the estimated external (watershed generated) total phosphorus load.

## PHOSPHORUS LOADS – Watershed, Sediment and In-Lake Capacity

Supporting documentation for the phosphorus loading analysis includes the following: water quality monitoring data from Maine DEP and the Volunteer Lake Monitoring Program and a phosphorus retention model (see Appendices).

- External total phosphorus loadings to Threecornered Pond originate from a combination of external (watershed + Anderson Pond) and internal (pond bottom sediment) sources of phosphorus. External phosphorus sources, averaging 214 kg annually, have been identified and accounted for by external land use alone.
- Total phosphorus loading from the associated upstream Anderson Pond (9 kg) accounts for external loading from the indirect watershed, determined on the basis of *flushing rate x volume x TP concentration*, and typical area gauged streamflow calculations (Jeff Dennis, Maine DEP, personal communication).
- The relative contribution of internal sources of total phosphorus within Threecornered Pond - in terms of pond sediment total phosphorus recycling - range from 10 to 20 kg with an average annual value of 15 kg.
- The load allocation (lake assimilative capacity) for all existing and future non-point pollution sources for Threecornered Pond is 183 kg of total phosphorus per year, based on a target goal of 15 ppb.



### **Recent and Current NPS/BMP Projects**

The Maine DEP completed a Diagnostic Feasibility study for the Webber Pond Watershed in 1981, which included Threecornered and Threemile ponds. This study documented significant water quality impairment to the ponds and provided recommended steps for restoration. In 1983, the KC-SWCD/SCS produced the Webber Pond Watershed Plan, which focused on supplementing the ongoing NPS reduction program by controlling internally recycled (pond sediment derived) phosphorus. The Plan included a listing of needed agricultural conservation practices in the watersheds of Threecornered, Threemile and Webber ponds.

A volunteer watershed survey has not been conducted for the Threecornered Pond watershed. The CRLA has several activities planned for 2003 including hosting educational meetings in conjunction with the Threecornered Pond Improvement Association, developing a newsletter, implementing demonstration projects using landowner cost-sharing, and providing technical assistance for roads, drainage, buffers, and erosion control (Reb Manthey, personal communication).

Conservation Corps, sponsored by the CRLA, provided free labor to landowners in the China Lake, and Webber, Threemile and Threecornered ponds watersheds for NPS BMP implementation. They operate for an eight to ten-week period during the summertime and will again be available to the Threecornered Pond watershed residents during the summer season of 2003. Work performed by the Corps in 2002 included trail development and NPS mitigation at the Augusta Bicentennial Nature Park.

In December of 2000, the CRLA initiated the Camp Road Runoff Abatement Project (#2001 R-09) which makes cost share funds available to organized road associations for help with road repairs. This project educates camp road users about the importance of good design and maintenance of camp roads and its connection to water quality. This successful project concluded in the fall of 2002 and similar funding will be sought in order to continue this type of NPS mitigation. Future funding granted to the CRLA will be available to Threecornered Pond watershed residents.

The Threecornered Pond Improvement Association took an important step forward by joining the China Region Lakes Alliance (CRLA) in 2002. Joining this Alliance will enable watershed residents to benefit from the established watershed management framework and available expertise. Other active and responsible organizations in place to deal with water quality issues include the Threecornered Pond Improvement Association (TPIA), the Kennebec County Soil and Water Conservation District (KC-SWCD) and Natural Resource Conservation Service (NRCS) offices, and the Maine DEP. During the 2002 season, the CRLA began working in the watershed, notably with technical assistance with camp roads and providing free labor and supervision of the Conservation Corps to complete erosion control work on trails and roads at the Bicentennial Nature Park. In the upcoming 2003 season, CRLA will assess in more detail the needs, including a potential watershed survey and watershed management plan. CRLA will also provide a Conservation Corps to assist landowners with implementing identified watershed NPS/BMPs. Implementing an adequate combination of residential and roadway BMPs will effectively reduce the existing external phosphorus load to Threecornered Pond.

## **PHOSPHORUS CONTROL ACTION PLAN**

Threecornered Pond is a waterbody that has impaired water quality due mostly to nonpoint sources and resultant internal (pond bottom) sediment recycling of phosphorus. Specific recommendations regarding Best Management Practices (BMPs) and actions to reduce external watershed total phosphorus loadings in order to improve water quality conditions in Threecornered Pond are as follows:

**Watershed Management:** There are many resources available to watershed stakeholders. An important step in lake restoration efforts for Threecornered Pond was joining the China Region Lakes Alliance in 2002. The CRLA provides education and outreach, offers free technical assistance to landowners for NPS BMP recommendations as well as free labor and potential cost-share funding for BMP implementation. The KC-SWCD also offers free technical assistance and potential grant project oversight and coordination. Interagency cooperation between the China Region Lakes Alliance, the Kennebec County Soil & Water Conservation District, the Threecornered Pond Improvement Association, the Maine DEP and Augusta, Vassalboro, and Windsor will help to maximize resources and efforts dedicated to protecting and enhancing the water quality of Threecornered Pond.

<b>Action Item # 1: Promote Available Technical/Financial/Educational Resources to Watershed Stakeholders</b>		
<b><u>Activity</u></b>	<b><u>Participants</u></b>	<b><u>Schedule &amp; Cost</u></b>
Host a meeting for watershed citizens	CRLA, TPIA, KCSWCD, MDEP, watershed citizens	Immediately—minimal cost

**Shoreline Residential Areas** have the greatest potential to negatively impact the water quality of Threecornered Pond. Much of the shoreline was noted for the presence of naturally vegetative buffers although some lots were rated as higher impact due to the need for more natural vegetation. It appears that sites lacking adequate buffers are dwellings that were recently constructed. These sites had large cleared areas and lawns. An effort should be undertaken to encourage landowners (especially new homeowners) to establish adequate and effective naturally vegetated buffers along the shoreline.

<b>Action Item # 2: Educate Watershed Citizens About Buffers</b>		
<b><u>Activity</u></b>	<b><u>Participants</u></b>	<b><u>Schedule &amp; Cost</u></b>
Develop a Buffer Awareness and Planting Campaign	CRLA, TPIA, watershed citizens, local nurseries	Annually beginning in 2003 <b>\$5,000/yr</b>

**Roadways** – Generally, lakeshore camp roads are not always designed and maintained properly, and can be a major source of soil erosion and sedimentation to lakes. During the summer of 2002, a survey of camp roads was conducted by MACD project staff with the assistance of the CRLA. Potential NPS pollution sources relating to roads include poor shaping, moderate to severe shoulder erosion and unstable culverts. More detailed information about potential NPS sites is available at the CRLA and will be used to assist in future BMP implementation.

A survey of state and town roads was conducted during the summer of 2002 by MACD project staff and the Lakes Specialist from the KC-SWCD. State and Town roads in the watershed would benefit from improved maintenance including the removal of winter sand at tributary crossings. For free technical assistance on proper road maintenance and potential cost-sharing on NPS BMP projects, contact the CRLA or the KC-SWCD.

<b>Action Item # 3: Implement Roadway BMPs</b>		
<u>Activity</u>	<u>Participants</u>	<u>Schedule &amp; Cost</u>
Implement roadway BMPs on camp roads and public roads	CRLA, KCSWCD, TPIA, MDEP, private road associations, municipal officials, watershed citizens	Annually beginning in 2003 <b>\$10,000/yr</b>

**Non-shoreline Residential and Commercial** properties should be considered as potential problem areas, especially those adjacent to lake tributary brooks and streams. These areas should be included in future education and outreach efforts as all residents within the watershed benefit from improved water quality in Threecornered Pond.

<b>Action Item # 4: Develop Stewardship Initiatives for Threecornered Pond tributaries</b>		
<u>Activity</u>	<u>Participants</u>	<u>Schedule &amp; Cost</u>
“Adopt” local streams to promote stewardship efforts including education and water quality monitoring	CRLA, KCSWCD, TPIA, MDEP Stream Team, watershed citizens, local schools	Annually beginning in 2003 <b>\$500/yr</b>

**Agriculture and Forestry** - Since the early 1980's the KC SWCD and USDA NRCS have worked cooperatively with landowners to install conservation practices in the watershed. For free technical assistance, potential cost-share funds or for more information about appropriate agricultural BMPs, contact the Kennebec County SWCD or NRCS offices in Augusta.

Individuals should consult with municipal officials for information about permit requirements within their municipality. Landowners, loggers, and foresters working in the watershed should contact the Maine Forest Service (1-800-367-0223 or 207-287-2791) for technical assistance or for a copy of the Forestry BMP Guidelines.

<b>Action Item # 5: Conduct Workshops for Agriculture and Forestry Operators</b>		
<u>Activity</u>	<u>Participants</u>	<u>Schedule &amp; Cost</u>
Conduct workshops encouraging the use of phosphorus control measures	CRLA, KCSWCD, NRCS, MFS, forestry and agriculture community	Annually beginning in 2003 <b>\$1,000/yr</b>

**Individual Action** by all watershed residents should be encouraged through continued education and outreach efforts. Actions should include retention or planting of natural vegetation of buffer strips, elimination of phosphorus-containing fertilizers, use of non-phosphate cleaning detergents and routine maintenance of septic systems.

Individuals are also encouraged to become active members of the Threecornered Pond Improvement Association. The Association is a valuable resource for watershed residents – and a broader, more active membership base will help ensure that lake watershed education and restoration efforts will be successful in the long run.

<b>Action Item # 6: Expand Watershed-Wide Homeowner Education</b>		
<u>Activity</u>	<u>Participants</u>	<u>Schedule &amp; Cost</u>
Increase outreach and education efforts to <u>watershed</u> citizens, including technical assistance	CRLA, KCSWCD, TPIA, MDEP	Annually beginning in 2003 <b>\$1,500/yr includes printing of educational materials</b>

**Threecornered Pond Improvement Association** – the TPIA should work with regional land trusts and the municipalities of Augusta and Vassalboro to ensure that the undeveloped land within the watershed remains in a pristine state.

<b>Action Item # 7: Investigate Land Conservation Opportunities within the Watershed</b>		
<u><b>Activity</b></u>	<u><b>Participants</b></u>	<u><b>Schedule &amp; Cost</b></u>
Coordinate land conservation efforts to ensure the future protection of sensitive areas within the watershed	TPIA, Regional Land Trusts	Immediately—Unknown

**Municipal Actions** should include ensuring public compliance with local and state water quality laws and ordinances (Shoreland Zoning, Erosion and Sedimentation Control Law, plumbing code, phosphorus control ordinance) primarily through education, and enforcement action only when necessary.

**WATER QUALITY MONITORING PLAN:** Historically, the water quality of Threecornered Pond has been monitored for 17 years since 1976 (Maine DEP and VLMP). Continued long-term water quality monitoring within Threecornered Pond will be conducted at least monthly, from May to October, through the continued efforts of Maine VLMP and CRLA in cooperation with Maine DEP. Under this planned, post-TMDL water quality-monitoring scenario, sufficient data will be acquired to adequately track seasonal and inter-annual variation and long-term trends in water quality in Threecornered Pond. A post-TMDL adaptive management status update report will be prepared five to ten years following EPA approval of this TMDL report.

### **Closing Statement**

Threecornered Pond is a unique waterbody relative to other area lakes by having a large amount of undeveloped shoreline and a relatively high flushing rate, over 3 times per year. Keeping this undeveloped land in a pristine state will undoubtedly benefit the future preservation of the water quality of the pond. Watershed stakeholders, including Augusta and Vassalboro, the CRLA, the TPIA and the KC-SWCD provide an ideal framework for managing the watershed and assuring that watershed citizens receive proper guidance on phosphorus mitigation. The extent of technical and financial resources available to watershed residents indicates that there is a high probability that future BMP implementation and educational outreach will begin to take place – a necessary part of restoring and protecting the water quality of Threecornered Pond.

## APPENDICES

### Introduction to Maine Lake TMDLs

- A. Water Quality, Priority Ranking, and Algae Bloom History
- B. Natural Environmental Background Levels
- C. Water Quality Standards and Target Goals
- D. Estimated Phosphorus Export by Land Use Class and Table 2
- E. Linking Water Quality and Pollutant Sources
- F. Load (LA) and Wasteload (WL) Allocations and
- G. Margin of Safety and Reasonable Assurance
- H. Seasonal Variation
- I. Watershed Phosphorus Control and Future Development
- J. Public Participation and Review Comments
- K. Threecornered Pond Specific and General References

## **Maine Lake TMDLs - Phosphorus Control Action Plans (PCAPs)**

**You may be wondering** what the acronym 'TMDL' represents and what it is all about. TMDL is actually short for 'Total Maximum Daily Load.' This information, no doubt, does little to clarify TMDLs in most people's minds. However, when we think of this as an annual phosphorus load (*Annual Total Phosphorus Load*), it begins to make more sense.

**Simply stated**, excess nutrients or phosphorus in lakes promote nuisance algae growth/blooms - resulting in the violation of water quality standards as measured by water clarity depths of less than 2 meters. A lake TMDL is prepared to estimate the total amount of total phosphorus that a lake can accept on an annual basis without harming water quality. Historically, development of TMDLs was first mandated by the Clean Water Act in 1972, and was applied primarily to *point sources* of water pollution. As a result of public pressure to further clean up water bodies, lake and stream TMDLs are now being prepared for watershed-generated *Non-Point Sources* (NPS) of pollution.

**Nutrient enrichment of lakes** through excess total phosphorus originating from watershed soil erosion has been generally recognized as the primary source of NPS pollution. Major land use activities contributing to the external phosphorus load in lakes include residential-commercial developments, roadways, agriculture, and commercial forestry. Statewide, there are 38 lakes in Maine which do not meet water quality standards due to excessive amounts of in-lake total phosphorus.

**The first Maine lake TMDL** was developed (1995) for Cobbossee Lake by the Cobbossee Watershed District (CWD) - under contract with Maine DEP and US-EPA. TMDLs have been approved by US-EPA for Madawaska Lake (Aroostook County), Sebasticook Lake, East Pond (Belgrade Lakes), and China Lake. PCAP-TMDLs are presently being prepared by Maine DEP, with assistance from the Maine Association of Conservation Districts (MACD) and County Soil and Water Conservation Districts (SWCDs) - for Mousam and Highland Lakes in southern Maine (final EPA review). Ongoing PCAP-TMDL lake studies include: Long and Highland lakes (Bridgton); Annabessacook & Little Cobbossee lakes & Pleasant & Upper Narrows Ponds - the latter four under separate contract with CWD. A non-MACD supported PCAP-TMDL for Unity Pond (Waldo County) is also being developed with the assistance of Unity College staff. PCAP-TMDL studies have also been initiated for Sabattus, Togus, and Lovejoy ponds.

**Lake TMDL reports** are based in part on available water quality data, including seasonal measures of total phosphorus, chlorophyll-a, Secchi disk transparencies, and dissolved oxygen-water temperature profiles. Actual reports include: a lake description; watershed GIS assessment and estimation of NPS pollutant sources; selection of a total phosphorus target goal (acceptable amount); allocation of watershed/land-use phosphorus loadings, and a public participation component to allow for stakeholder review.

**TMDLs are important tools** for maintaining and protecting acceptable lake water quality. They are primarily designed to 'get a handle' on the magnitude of the NPS pollution problem and to develop plans for implementing Best Management Practices (BMPs) to address the problem. *Development of phosphorus-based LAKE TMDLs are not intended by Maine DEP to be used for regulatory purposes.* Landowners and watershed groups are eligible to receive technical and financial assistance from state and federal natural resource agencies to reduce watershed total phosphorus loadings to the lake.

**A. Water Quality Monitoring:** (Source: Maine DEP and VLMP 2002) Water quality monitoring data for Threecornered Pond has been collected in 17 of the past 27 years since 1976. This water quality assessment is based on 17 years of Secchi disk transparency (SDT) measures, combined with 12 years of epilimnion core total phosphorus (TP) data, and 15 years of chlorophyll-a and associated water chemistry monitoring data.

**Water Quality Measures:** Threecornered Pond, a lightly colored water (30-35 SPUs) has an overall range of SDT measures from 1.1 to 4.7 meters, with an average of 3.2 meters (10.5 ft.); an epilimnion core TP range of 9 to 31 with an average of 20 parts per billion (ppb), and chlorophyll-a measures ranging from 2.5 to 28.7 with an average of 9.4 ppb. Recent dissolved oxygen (DO) profiles indicate low levels of DO in deep areas of the lake and historical records of severe oxygen depletion below the thermocline dating back to the 1940's (Maine DEP 1981). Late summer dissolved oxygen levels in 2002 remained fairly low (0-4 ppm) with ca. 50% of the water column (lower 4-5 meters) unsuitable for salmonid species (e.g., brown trout). The potential for total phosphorus to leave the bottom sediments and become available to algae in the water column (internal loading) is moderate to high, according to Maine DEP (2001).

**Priority Ranking, Pollutant of Concern and Algae Bloom History:** Threecornered Pond is listed on the State's 1998 and 2002 (draft) 303(d) list of waters in non-attainment of water quality standards. The Threecornered Pond TMDL has been developed for total phosphorus, the major limiting nutrient to algae growth in freshwater lakes in Maine.

The water quality of Threecornered Pond during 2002 appeared to improve as the summer progressed. Minimum water transparencies of 2.7 to 2.8 meters were observed in May and June and maximum water clarity (3.8 to 3.9 meters) was measured in mid to late August. Epilimnion core total phosphorus measures (14-36 ppb) and chlorophyll-a (13-32 ppb) levels remained fairly high. Based on minimum water transparencies, nuisance blue-green algae blooms were evident only during the summers of 1985 (1.8 m), 1988 (1.1 m), and 1990 (1.2 m)., however, many of the intervening years were not monitored (1982-83, 1993, 95, 96, 97, 99).

**B. Natural Environmental Background Levels** for Threecornered Pond were not separated from the total nonpoint source load because of the limited and general nature of available information. Without more and detailed site-specific information on nonpoint source loading, it is very difficult to separate natural background from the total nonpoint source load (US-EPA 1999). There are no known point sources of pollutants to Threecornered Pond (MACD 2002).

### **C. WATER QUALITY STANDARDS and TARGET GOALS**

**Maine State Water Quality Standard:** Standards for nutrients which are narrative, are as follows (*July 1994 Maine Revised Statutes Title 38, Article 4-A*): "Great Ponds Class A (GPA) waters shall have a stable or decreasing trophic state (based on appropriate measures, e.g., total phosphorus, chlorophyll a, Secchi disk transparency) subject only to natural fluctuations, and be free of culturally induced (summertime) algae blooms which impair their potential use and enjoyment."

Maine DEP's functional definition of nuisance algae blooms include episodic occurrence of Secchi disk transparencies (SDTs) < 2 meters for lakes with low levels of apparent color (<26 SPU) and for higher color lakes where low SDT readings are accompanied by elevated chlorophyll a levels. Threecornered Pond is a colored lake (average color 30 - 35 SPU), with an average SDT of 3.2 m (10.5 feet), in association with average chlorophyll a levels of 9.4 ppb (VLMP 2002). Currently, Threecornered Pond does not meet water quality standards due to sporadic historically recorded annual summertime nuisance algae blooms. This water quality assessment uses historic documented conditions as the primary basis for comparison. Given the context of "impaired use and enjoyment," along with a realistic interpretation of Maine's goal-oriented Water Quality Standards (WQS), we have determined that episodic, non-cyanobacteria based algae blooms (e.g. diatoms), limited to the fall or spring periods only, are in WQS attainment for GPA waters.

**Designated Uses and Antidegradation Policy:** Threecornered Pond is designated as a GPA (Great Pond Class A) water in the Maine DEP state water quality regulations. Designated uses for GPA waters in general include: water supply; primary/secondary contact recreation (swimming and fishing); hydroelectric power generation; navigation; and fish and wildlife habitat. No change of land use in the watershed of a Class GPA water body may, by itself or in combination with other activities, cause water quality degradation that would impair designated uses of downstream GPA waters or cause an increase in their trophic state. Maine's anti-degradation policy requires that "existing in-stream water uses, and the level of water quality necessary to sustain those uses, must be maintained and protected."

**Numeric Water Quality Target:** The numeric (in-lake) water quality target for Threecornered Pond is set at 15 ppb total phosphorus (183 kg TP/yr). Since numeric criteria for phosphorus do not exist in Maine's state water quality regulations - and would be less accurate targets than those derived from this study - we employed Best Professional Judgment to select a target in-lake total phosphorus concentration that would attain the narrative water quality standard. Spring-time (epilimnion core) total phosphorus levels in Threecornered Pond approximated 15 ppb during the time period 1979 - 1992. In-lake (epilimnion core) total phosphorus summer-time (June through August) measures averaged 16.5 ppb (non-bloom conditions). In summary, the numeric water quality target goal of 15 ppb for total phosphorus in Threecornered Pond was based on available water quality data (average epilimnion grab/core samples) corresponding to non-bloom conditions, as reflected in suitable (water quality attainment) measures of both Secchi disk transparency (> 2.0 meters) and chlorophyll-a (< 8.0 ppb).

#### **D. Estimated Phosphorus Export by Land Use Class**

The table on the following page details the numerical data used to determine external phosphorus loading for the Threemile Pond watershed. The key below explains the columns and the narrative that follows the table explains the land use categories.

#### **Total Phosphorus Land Use Loads**

Estimates of total phosphorus export from different land uses found in the Threecornered Pond direct watershed are presented in Table 3 and represent the extent of external phosphorus loading to the lake. Total phosphorus loading from the associated upstream Anderson pond account for loading from the indirect watershed (9 kg/TP/yr), determined on the basis of *flushing rate x volume x TP concentration*, and typical area gauged streamflow calculations (Jeff Dennis, personal communication).

#### **Key for Columns depicted in Table 3**

**Land Use:** The land use category that was analyzed for this report

**Total Area Acres:** The area of each land use as determined by GIS mapping, aerial photography, Delorme Topo USA software, and field reconnaissance.

**Total Area Hectares:** One Acre = .404 hectares

**TP Coeff. Avg kg/P/ha:** The selected coefficient for each land use category. The Total Phosphorus coefficient is determined from previous research – usually the median value if it is listed by the author. The coefficient is often adjusted using best professional judgment based on conditions including soil type, slope, and BMPs installed.

**TP Coeff. Avg kg TP: =** Total Hectares x TP Coefficient

**TP Coeff. Range kg/P/ha:** The range of the coefficient values listed in the various literature associated with the corresponding land use.

**Tot Land Area %:** The percentage of the watershed covered by the land use.

**TP Exp Avg %:** The percentage of estimated Phosphorus export by the land use.

**Table 3: Estimated Phosphorus Load by Land Use for the Threecornered Pond Watershed**

LAND USE	Total Area Acres	Total Area Hectares	TP Coeff. Avg. kg/P/ha	TP Exp. Avg. kg TP	TP Coeff. Range kg/P/ha	Tot Land Area %	TP Exp Avg %
<b>Agricultural and Forestry practices</b>	2,471	0.40469					
Corn Crops	31	12	1.5	18.6	0.26 - 18.6	0.9%	8.7%
Hayland	65	26	0.65	17.0	0.1 - 2.9	2.0%	8.0%
Low-Intensity Hayland	37	15	0.20	3.0	0.3 - 0.6	1.1%	1.4%
Operated Forestland	171	69	0.4	27.7	0.2 - 0.5	5.2%	12.9%
<b>Sub-totals</b>	<b>303</b>	<b>123</b>		<b>66</b>		<b>9%</b>	<b>31%</b>
<b>Shoreline development</b>							
Low impact residential	9	3	0.25	0.9	0.25 - 1.75	0.3%	0.4%
Medium impact residential	11	4	0.5	2.1	0.4 - 2.2	0.3%	1.0%
High impact residential	3	1	0.7	0.8	0.56 - 2.7	0.1%	0.4%
Septic Systems		Septic model		5	5 - 16		2.3%
Camp & Private Roads	9	4	2	7.4	0.63 - 10.1	0.3%	3.5%
Recreational	4	2	2	3.2	0.14 - 4.9	0.1%	1.5%
<b>Sub-totals</b>	<b>35</b>	<b>14</b>		<b>19</b>		<b>1%</b>	<b>9%</b>
<b>Non-shoreline development</b>							
State Roads	19	8	1.5	11.3	0.63 - 10.1	0.6%	5.3%
Town Roads	23	9	1.5	14.1	0.63 - 10.1	0.7%	6.6%
Trails	1	1	2	1.1	0.63 - 10.1	0.0%	0.5%
Low Density Residential	66	27	0.25	6.7	0.25 - 1.75	2.0%	3.1%
Commercial	5	2	1.5	3.0	0.77 - 4.18	0.2%	1.4%
<b>Sub-totals</b>	<b>115</b>	<b>46</b>		<b>36</b>		<b>4%</b>	<b>17%</b>
<b>Total Ag/Forestry/Development</b>	<b>453</b>	<b>183</b>		<b>122</b>		<b>14%</b>	<b>57%</b>
Inactive/Passively Managed Forest	1904	770	0.04	30.8	0.01 - 0.04	58.2%	14.4%
Wetlands	266	108	0.2	21.5	0.02 - 0.83	8.1%	10.1%
Scrub Shrub	262	106	0.1	10.6	0.05	8.0%	5.0%
Reverting Fields	204	83	0.2	16.5	0.1 - 0.2	6.2%	7.7%
Bare Land	2	1	0.98	0.7		0.1%	0.3%
<b>Undeveloped</b>	<b>2,639</b>	<b>1,067</b>		<b>80</b>		<b>81%</b>	<b>37%</b>
<b>Total Open Water</b>	<b>180</b>	<b>73</b>	<b>0.16</b>	<b>12</b>	<b>0.11 - 0.21</b>	<b>6%</b>	<b>5%</b>
<b>TOTAL DIRECT WATERSHED</b>	<b>3,272</b>	<b>1,324</b>		<b>214</b>		<b>100%</b>	<b>100%</b>

Total phosphorus loading measures are expressed as a range of values to reflect the degree of uncertainty associated with such relative estimates (Walker 2000). Watershed total phosphorus loadings were primarily determined using published literature and locally-derived export coefficients as found in Reckhow et al. (1980), Dennis (1986), Dennis et al. (1992), and Bouchard et al. (1995) for roadways, agriculture and other types of land uses (institutional, commercial).

Selected (range of) phosphorus loading coefficients in Table 3 have been adjusted for the estimated bioavailability of the runoff sources according to available literature (Lee et al. 1980 and Sonzogni et al. 1982) and tempered by best professional judgment (Jeff Dennis, Maine DEP, personal communication). Substantial changes include shoreline roads and residential development (approximately 50% reduction from total to bioavailable phosphorus). However, these changes do not effectively alter the conclusions and recommendations of the PCAP-TMDL report regarding identified needs and implementation plans for required watershed NPS/BMPs.

**Agricultural and Forestry Practices:** Total phosphorus loading coefficients applied to agricultural practices were adopted from Reckhow 1980 (hay land 1.0 kg/TP/ha, pasture 0.81 kg/TP/ha) and Bouchard et al. 1995 (low-intensity hay land 0.6 kg/TP/ha) and from Maine DEP (1989) studies (row crops 1.5 kg/TP/ha).

The total phosphorus loading coefficient applied to managed forestlands was adopted directly from an earlier Annabessacook Lake 1977 study (0.4 kg/P/ha).

**Shoreline Residential Lots (House and Camp):** Residential land use comprised three relative impact categories - low, medium and high impact (Table 2). The range of total phosphorus loading coefficients used (0.25 – 0.7 kg/ha/yr) were developed using information on residential lot stormwater export of algal available phosphorus from Dennis et al (1992) .

**Private Camp Roads:** Total phosphorus loading coefficients for private camp roads (2.0 kg/TP/ha) were chosen based on studies from rural Maine highways (Dudley et al. 1997).

**Public Roadways:** Town and state roadways (17 ha) were assigned a total phosphorus loading rate of 1.5 kg per hectare per year. This coefficient was chosen based on studies from rural Maine highways (Dudley et al. 1997).

**Non-Shoreline Development:** Consists of all lands outside the immediate shoreline of Threecornered Pond, including residential areas and commercial areas. Non-shoreline residential areas in the watershed are best characterized as low density residential (reflected in the 0.25 TP loading coefficient) and limited commercial development.

**Non-Cultural Phosphorus Loading:** The phosphorus loading coefficient for inactive-passively managed forested land (0.04) is based on a New England regional study (Likens et al 1977).

**Atmospheric Deposition and Dry Fallout** represents the lake surface waters (180 ha) . The total phosphorus loading coefficient chosen (0.16 kg/P/ha) is similar to that used for the China Lake TMDL (Kennebec County). The upper range (0.21 kg/P/ha) generally reflects a watershed that is 50 percent forested, combined with agricultural areas interspersed with urban/suburban land uses (Reckhow et al. 1980).

## **E. LINKING WATER QUALITY and POLLUTANT SOURCES**

**Loading Capacity:** The Threecornered Pond loading assimilative capacity is set at 183 kg TP/yr of total phosphorus. The Threecornered Pond TMDL is expressed as an annual load as opposed to a daily load. As specified in 40 C.F.R. 130.2(i), TMDLs may be expressed in terms of either mass per unit time, toxicity, or other appropriate measures. It is thought appropriate and justifiable to express the Threecornered Pond TMDL as an annual load because the lake basin has a flushing rate of (3.24) – more than twice the average for Maine lakes.

**Linking Pollutant Loading to a Numeric Target:** The basin loading assimilative capacity for Threecornered Pond was set at 183 kg/yr of total phosphorus to meet the numeric water quality target of 15 ppb of total phosphorus. A phosphorus retention model, calibrated to in-lake phosphorus data, was used to link phosphorus loading to the numeric target.

**Supporting Documentation for the Threecornered Pond TMDL (PCAP) Analysis:** includes the following: Maine DEP and VLMP water quality monitoring data and specification of a phosphorus retention model – including both empirical models and retention coefficients.

**Total Phosphorus Retention Model** (after Dillon and Rigler 1974 and others)

$$L = P (A z p) / (1-R) \text{ where,}$$

183 = L = external total phosphorus load capacity (kg TP/year)  
 15.0 = P = spring overturn total phosphorus concentration (ppb)  
 0.73 = A = lake basin surface area (km<sup>2</sup>)  
 3.3 = z = mean depth of lake basin (m)                      **A z p = 7.8**  
 3.24 = p = annual flushing rate (flushes/year)  
 0.64 = 1- R = phosphorus retention coefficient, where:  
 0.36 = R = 1 / (1+ sq.rt. p) (Larsen and Mercier 1976)

Previous use of the Vollenwieder (Dillon and Rigler 1974) type empirical model for Maine lakes, e.g., Cobbossee, Madawaska, Sebasticook, East Pond and China, Mousam and Highland Lake, Webber and Threemile TMDLs (Maine DEP 2000-2002) have shown this approach to be effective in linking watershed total phosphorus (external) loadings to existing in-lake total phosphorus concentrations.

### **Strengths and Weaknesses in the Overall TMDL Analytical Process**

The Threecornered Pond TMDL was developed using existing lake water quality monitoring data, derived watershed export coefficients (Reckhow et al. 1980, Maine DEP 1981 and 1989, Dennis 1986, Dennis et al. 1992, Bouchard et al. 1995, Soranno et al. 1996, and Mattson and Isaac 1999) and a phosphorus retention model which incorporates both empirically derived and observed retention coefficients (Vollenwieder 1969, Dillon 1974, Dillon and Rigler 1974 a and b, and 1975, Kirchner and Dillon 1975). Use of the Larsen and Mercier (1976) total phosphorus retention term, based on localized data (northeast and north-central U.S.) from 20 lakes in the US-EPA National Eutrophication Survey (US-EPA-NES) provides a more accurate model for northeastern regional lakes.

#### **Strengths:**

- ❖ Approach is commonly accepted practice in lake management
- ❖ Makes best use of available water quality monitoring data
- ❖ Export coefficients were derived from extensive data bases, and were determined to be appropriate for the application lake.

#### **Weaknesses:**

- ❖ Inherent uncertainty of TP load estimates (Reckhow 1979, Walker 2000) and associated variability and generality of TP loading coefficients.

**Critical Conditions** in Threecornered Pond occur during the summertime, when the potential (frequency and occurrence) of nuisance algae blooms are greatest. The loading capacity of 15 ppb of total phosphorus was set to achieve desired water quality standards during this critical time period, and will also provide adequate protection throughout the year (see Seasonal Variation section).

## F. LOAD ALLOCATIONS (LA's)

The load allocation (lake capacity) for all existing and future non-point pollution sources for Threecornered Pond is 183 kg TP/yr, as derived from the empirical phosphorus retention model based on a target goal of 15 ppb (see Loading Capacity discussion). Reductions in nonpoint source phosphorus loadings are expected from the continued implementation of best management practices (see BMP Implementation Plan summary). As previously mentioned, it was not possible to separate natural background from nonpoint pollution sources in this watershed because of the limited and general nature of the available information. As in other Maine TMDL lakes (see Sebasticook Lake, East Pond, China Lake, Webber Pond, and Threemile Pond TMDLs), in-lake nutrient loadings in Threecornered Pond originate from a combination of external (watershed) and to a much lesser extent, internal (sediment) sources of total phosphorus. External TP sources, averaging 214 kg annually have been identified and accounted for in the land-use breakdown portrayed in Table 3.

**Internal Lake Sediment Phosphorus Load:** The relative contribution of internal sources of total phosphorus within Threecornered Pond - in terms of sediment recycling - were analyzed (using lake volume-weighted mass differences between early and late summer) and estimated on the basis of water column TP data from 1991-92 and 2001-02. These were the only years for which complete lake profile TP concentration measures were available to derive reliable estimates of internal lake loads. Among these years, nuisance algae blooms were not evident. The estimated annual internal TP loading within the sediments of Threecornered Pond (10 to 20 kg) is fairly minimal at this time, but has more than doubled in the past decade (1991-2002).

**WASTE LOAD ALLOCATIONS (WLA's):** As there are no known existing point sources of pollution in the Threecornered Pond watershed, the waste load allocation for all existing and future point sources is set at 0.

**G. MARGIN OF SAFETY (MOS) and REASONABLE ASSURANCE:** An implicit margin of safety was incorporated into the Threecornered Pond TMDL through the conservative selection of the numeric water quality target, as well as the selection of relatively conservative phosphorus export loading coefficients for cultural pollution sources (Table 3). Based on both the Threecornered Pond historical records and a summary of statewide Maine lakes water quality data for colored (> 26 SPU lakes) - the target of 15 ppb (183 kg TP/yr) in Threecornered Pond) represents a highly conservative goal to assure attainment of Maine DEP water quality goals of non-sustained and non-repeated blue-green summer-time algae blooms due to NPS pollution or cultural eutrophication. The statewide database for naturally colored Maine lakes indicate that summer nuisance algae blooms (growth of algae which causes Secchi disk transparency to be less than 2 meters) are more likely to occur at 18 ppb or above. The difference between the in-lake target of 15 ppb (183 kg) and 17 ppb (207 kg) represents a 13% implicit margin of safety for Threecornered Pond.

**H. SEASONAL VARIATION:** The Threecornered Pond TMDL is protective of all seasons, as the allowable annual load was developed to be protective of the most sensitive time of year – during the summer, when conditions most favor the growth of algae and aquatic macrophytes. With a hydraulic retention time of 3.24 flushes/year, the average annual phosphorus loading is most critical to the water quality in Threecornered Pond. Maine DEP lake biologists, as a general rule, use more than six flushes annually (bi-monthly) as the cut-off for considering seasonal variation as a major factor (to distinguish lakes vs. rivers) in the evaluation of total phosphorus loadings in aquatic environments in Maine. The best management practices (BMPs) proposed for the Threecornered Pond watershed have been designed to address total phosphorus loading during all seasons.

**I. WATERSHED PHOSPHORUS CONTROL AND FUTURE DEVELOPMENT:** The Maine DEP water quality goal of maintaining a stable trophic state includes a reduction of current P-loading which accounts for recent P-loading and potential future development in the watershed. The methods used by Maine DEP to estimate future growth (Dennis et al. 1992) are inherently conservative, as they

provide for relatively high-end regional growth estimates and largely unmitigated P-export from new development. This provides an additional unquantified margin of safety for attainment of state water quality goals.

## **J. PUBLIC PARTICIPATION AND REVIEW COMMENTS**

**PUBLIC PARTICIPATION** - Adequate ('full and meaningful') public participation in the Threecornered Pond TMDL development process was ensured - during which land use and phosphorus load reductions were discussed - through the following avenues:

1. MACD project staff Jodi Michaud Federle attended numerous CRLA board meetings. Updates on the lake TMDL development process were provided. (*The board is made up of members of the lake associations of Webber Pond, Threemile Pond, Threecornered Pond and China Lake, as well as the Kennebec Water District and the meetings are attended by the Executive Director of the CRLA*).
2. During the summer and fall of 2001 and 2002, MACD project staff - particularly Threecornered Pond coordinator Jodi Michaud Federle - made numerous visits to the Vassalboro town office, the City of Augusta, and to the Kennebec County SWCD office in order to compile necessary watershed inventory information.
3. On February 28, 2002, a Locally-lead Watershed Conservation meeting was hosted by the Kennebec County SWCD at the China Town Office. The meeting was attended by approximately 12 people, including residents of the Webber, Threemile and Threecornered Pond watersheds. The Lake TMDL studies were explained and discussed. A follow-up Watershed Conservation meeting was held on March 28, 2002, hosted by the KC-SWCD at the Vassalboro Town Office. This meeting was attended by 14 people, including residents of the Webber, Threemile and Threecornered Pond watersheds. Water quality information used in creating the TMDL report was supplied to watershed residents.
4. The China Region Lakes Alliance's 2002 spring newsletter featured an article about the TMDL studies for Webber, Threemile and Threecornered ponds.
5. A TMDL presentation was made at the Threecornered Pond Improvement Association's 2002 annual meeting, attended by approximately 30 to 35 people.

### **Preliminary Stakeholder Review Comments**

A preliminary stakeholder review draft Threecornered Pond TMDL report was submitted to 13 individuals who received an electronic or hard copy version of the report on December 20, 2002, and were requested to comment by the end of a three-week review period. The following summarized comments were provided:

Joan Jones, President, Threecornered Pond Improvement Association—provided written comments regarding clarifications to help the layperson better understand the report as well as specifics regarding how to best reduce the external phosphorus input to the lake.

Reb Manthey, CRLA, Executive Director—provided written general comments and minor edits.

## REFERENCES

### Specific References

- Maine Department of Environmental Protection. 1982. Webber, Threemile, Threecornered Ponds Diagnostic Feasibility Study. Maine DEP, Augusta, Maine (EPA 314 Grant # 0012070).
- Maine Department of Marine Resources, Atlantic Sea-Run Salmon Commission and Department of Inland Fisheries & Wildlife. 1986. Lower Kennebec River Anadromous Fish Restoration Plan and Inland Fisheries Management Overview. (P.L. 89-304 Anadromous Fish Act, Project: ME: AFC-23).
- Threecornered Pond Improvement Association. 2002. Threecornered Pond Water Level Management Plan (Draft).
- United States Department of Agriculture Soil Conservation Service. 1978. Soil Survey of Kennebec County, Maine. USDA, Washington, DC.

### Lake TMDL General References

- Basile, A.A. and M.J. Vorhees. 1999. A practical approach for lake phosphorus Total Maximum Daily Load (TMDL) development. *US-EPA Region I, Office of Ecosystem Protection, Boston, MA* (July 1999).
- Bouchard, R., M. Higgins, and C. Rock. 1995. Using constructed wetland-pond systems to treat agricultural runoff: a watershed perspective. *Lake and Reservoir Management* 11(1):29-36.
- Correll, D.L., T.L. Wu, E.S. Friebele, and J. Miklas. 1978. Nutrient discharge from Rhode Island watersheds and their relationships to land use patterns. In: *Watershed Research in Eastern North America: A workshop to compare results*. Volume 1, February 28 - March 3, 1977. (mixed pine/hardwoods)
- Dennis, J. 1986. Phosphorus export from a low-density residential watershed and an adjacent forested watershed. *Lake and Reservoir Management* 2:401-407.
- Dennis, J., J. Noel, D. Miller, C. Elliot, M.E. Dennis, and C. Kuhns. 1992. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. *Maine Department of Environmental Protection*, Augusta, Maine.
- Dillon, P.J. 1974. A critical review of Vollenweider's nutrient budget model and other related models. *Water Resources Bulletin* 10:969-989.
- Dillon, P.J. and F.H. Rigler. 1974a. The phosphorus-chlorophyll relationship for lakes. *Limnology and Oceanography* 19:767-773.
- Dillon, P.J. and F.H. Rigler. 1974b. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. *Journal of the Fisheries Research Board of Canada* 31:1771-1778.
- Dillon, P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. *Journal of the Fisheries Research Board of Canada* 32:1519-1531.

- Dudley, R.W., S.A. Olson, and M. Handley. 1997. A preliminary study of runoff of selected contaminants from rural Maine highways. U.S. Geological Survey, Water-Resources Investigations Report 97-4041 (DOT, DEP, WRI), 18 pages.
- Gasith, Avital and Sarig Gafny. 1990. Effects of water level fluctuation on the structure and function of the littoral zone. Pages 156-171 (Chapter 8) *in*: M.M. Tilzer and C. Serruya (eds.), *Large Lakes: Ecological Structure and Function*, Springer-Verlag, NY.
- Jemison, J.M. Jr., M.H. Wiedenhoeft, E.B. Mallory, A. Hartke, and T. Timms. 1997. A Survey of Best Management Practices on Maine Potato and Dairy Farms: Final Report. University of Maine Agricultural and Forest Experiment Station, Misc. Publ. 737, Orono, Maine.
- Kirchner, W.B. and P.J. Dillon. 1975. An empirical method of estimating the retention of phosphorus in lakes. *Water Resources Research* 11:182-183.
- Larsen, D.P. and H.T. Mercier. 1976. Phosphorus retention capacity of lakes. *Journal of the Fisheries Research Board of Canada* 33:1742-1750.
- Maine Department of Environmental Protection. 1999. Cobboossee Lake (Kennebec County, Maine) Final TMDL Addendum (to Monagle 1995). *Maine Department of Environmental Protection*, Augusta, Maine.
- Mattson, M.D. and R.A. Isaac. 1999. Calibration of phosphorus export coefficients for total maximum daily loads of Massachusetts lakes. *Journal of Lake and Reservoir Management* 15(3):209-219.
- Michigan Department of Environmental Quality. 1999. Pollutant Controlled Calculation and Documentation for Section 319 Watersheds *Training Manual*. Michigan DEQ, Surface Water Quality Division, Nonpoint Source Unit.
- Monagle, W.J. 1995. Cobboossee Lake Total Maximum Daily Load (TMDL): Restoration of Cobboossee Lake through reduction of non-point sources of phosphorus. *Prepared for ME-DEP by Cobboossee Watershed District*.
- Nurnberg, G.K. 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. *Limnology and Oceanography* 29:111-124.
- Nurnberg, G.K. 1987. A comparison of internal phosphorus loads in-lakes with anoxic hypolimnia: Laboratory incubation versus in situ hypolimnetic phosphorus accumulation. *Limnology and Oceanography* 32(5):1160-1164.
- Nurnberg, G.K. 1988. Prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 45:453-462.
- Pearce, Andrea, R. 2000. Phosphorus Cycling in Maine Lakes: A Geochemical Study. University of Maine, Orono, Department of Civil Engineering, Master's Thesis.
- Reckhow, K.H. 1979. Uncertainty analysis applied to Vollenweider's phosphorus loading criteria. *Journal of the Water Pollution Control Federation* 51(8):2123-2128.
- Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011,

US-EPA, Washington, D.C.

- Reckhow, K.H., J.T. Clemens, and R.C. Dodd. 1990. Statistical evaluation of mechanistic water-quality models. *Journal Environmental Engineering* 116:250-265.
- Riley, E.T. and E.E. Prepas. 1985. Comparison of phosphorus-chlorophyll relationships in mixed and stratified lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 42:831-835.
- Rippey, B., N.J. Anderson, and R.H. Foy. 1997. Accuracy of diatom-inferred total phosphorus concentrations and the accelerated eutrophication of a lake due to reduced flushing and increased internal loading. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2637-2646.
- Schroeder, D.C. 1979. Phosphorus Export From Rural Maine Watersheds. *Land and Water Resources Center, University of Maine, Orono, Completion Report*.
- Singer, M.J. and R.H. Rust. 1975. Phosphorus in surface runoff from a (northeastern United States) deciduous forest. *Journal of Environmental Quality* 4(3):307-311.
- Sonzogni, W.C., S.C. Chapra, D.E. Armstrong, and T.J. Logan. 1982. Bioavailability of phosphorus inputs to lakes. *Journal of Environmental Quality* 11(4):555-562.
- Soranno, P.A., S.L. Hubler, S.R. Carpenter, and R.C. Lathrop. 1996. Phosphorus loads to surface waters: a simple model to account for spatial pattern. *Ecological Applications* 6(3):865-878.
- Sparks, C.J. 1990. Lawn care chemical programs for phosphorus: information, education, and regulation. U.S. Environmental Protection Agency, Enhancing States' Lake Management Programs, pages 43-54. [Golf course application]
- Tietjen, Elaine. 1986. Avoiding the China Lake Syndrome. Reprinted from *Habitat* - Journal of the Maine Audubon Society, 4 pages.
- U.S. Environmental Protection Agency. 1999. Regional Guidance on Submittal Requirements for Lake and Reservoir Nutrient TMDLs. *US-EPA Office of Ecosystem Protection*, New England Region, Boston, MA.
- U.S. Environmental Protection Agency. 2000a. Cobbossee Lake TMDL Approval Documentation. US-EPA/NES, January 26, 2000.
- U.S. Environmental Protection Agency. 2000b. Madawaska Lake TMDL Approval Documentation. US-EPA/NES, July 24, 2000.
- U.S. Environmental Protection Agency. 2001a. Sebasticook Lake TMDL Approval Documentation. US-EPA/NES, March 8, 2001.
- U.S. Environmental Protection Agency. 2001b. East Pond TMDL Approval Documentation. US-EPA/NES, 2001.
- U.S. Environmental Protection Agency. 2001c. China Lake TMDL Approval Documentation. US-EPA/NES, 2001.
- Vollenweider, R.A. 1969. Possibility and limits of elementary models concerning the budget of substances in lakes. *Arch. Hydrobiol.* 66:1-36.